BOOZE

Protective Coatings for Dryer Cars

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PROTECTIVE COATINGS FOR DRYER CARS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Macdonald Charles Booze

ENTITLED PROTECTIVE COATINGS FOR DRYER CARS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

in Ceramics

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1. Introduction

The subject of protection for dryer cars is an important one to the ceramic manufacturer using waste heat dryers.The first cost of,and expense for repairs on the cars are large so that the rapid corrosion of the metal means a fairly large loss to the owner.

The decks of the cars are made of soft,rolled steel channel bars of about 3/16 inch thickness,five feet in length, and two inches wide,supported at both ends and in the middle.The corrosive action of the dryer gases is so great that the bars become rusted out within a years time,and are not able to carry the weight of a load of dry clay without bending or breaking. In extreme cases, these bars have disintegrated within a period of six months.

Realizing the economic value to be gained by the clay operator by prolonging the life of the dryer cars, the following data by others on the corrosion of iron and steel and protective coatings is given together with tests by the writer upon coatings which seemed to be the most promising.

There has been a wealth of material written upon the causes of corrosion and the means of protection against it. Instances are many where one writer makes a statement in contradiction to another.In the following, an attempt has been made to quote from the more recognized authorities, and to accept results where the majority of the writers came to the same general agreement. Results proved by experiment were, in every case, given

preference over theoretical ideas.

11. Agents Causing Failure of the Iron and Protective Coatings

These may be divided into two classes. First, chemical agents; and second, physical agents.

The chemical action is the more important since it is the more injurious. The agents under this head are liquid and gaseous acids, and oxygen.

The physical agents to be considered are heat, jars from falling bricks etc., and abrasion by friction.

Sulphurous acid is by far the most important acid to be considered[1]. Carbonic acid may be present in the dryer gases, but its corrosive action is not to be compared with that of the former. The sulphurous acid is formed from the sulphur dioxide obtained from coal burned in the kilns, and water vapor from the wet clay. It is deposited upon the cars upon condensation of the water vapor in the dryer gases, and thus begins its action.

Sang[2] states that of all the agents in the air which accelerate rusting, especially near cities where much fuel is consumed, sulphur dioxide and soot are the most destructive.

Since the carbonic acid in the open air does not readily corrode a steel structure, the sulphurous acid is evidently the more active acid and hence is the only one which will be considered.

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[1] 1-Kent in "Journal of the Franklin Institute", vol.99,p.437

[2] 2-"Corrosion of Iron and Steel", p. 62

The physical agents, in general, aid only in the failing of the protective coating. Heat accelerates the action of the acids upon the iron, and causes a physical change in some paints, such as cracking and brittleness in an oil paint, and softness in an asphaltic coating.

Jars and blows from falling bricks etc., to which the cars are always subjected, chip off a brittle coating and predetermine the failing of an enamel or other hard and brittle covering.

The paints are constantly subjected to abrasion through hard clay bodies sliding upon the surface of the cars, and ability to withstand such wear is a necessary quality of a satisfactory coating.

Rust begins at any spot where the metal is not covered, and spreads over the surface of the iron in all directions. It clings very weakly to the surface of the metal, and as a result, scales off easily - taking the paint with it and exposing an unprotected surface[1].

Spennrath[2] states that rust aids the further formation of rust through being porous and holding water and corrosive agents in contact with the surface of the iron.

Structural material coming from the mill is usually coated with an oxide called mill scale which adheres firmly to the surface of the metal. It is very often the case that paint is applied over this scale. If the material has stood for any length

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1- "Protective Coatings for Iron" by Spennrath, p. 4

2- "Protective Coatings for Iron", p. 20

of time before being painted, moisture has penetrated the scale and begun invisible corrosion[1]. This continues under the paint until the scale becomes loosened from the underlying metal and falls off, which usually happens within a period of three or four months. Sang[2] states that iron in contact with mill scale, when exposed to the atmosphere, rusts about fifty per-cent faster than the bare metal.

The scale is often removed before painting by allowing rust to form, then cleaning the surface with wire brushes or a sand-blast[3,4,5].

Previous experiments have shown that oxygen and water vapor alone are not active in producing rust[6]. However, very small quantities of carbonic, sulphuric, or sulphurous acids cause rapid corrosion of iron and steel[7].

Three theories have been advanced concerning the formation of rust;

1- The carbonic acid theory, founded upon investigations by Calvert who asserts that carbonic acid is necessary in the formation of rust. This theory is disproved by several men[8] who showed that rusting takes place very rapidly in the absence of carbonic acid.

1- Friend's "Corrosion of Iron and Steel" p. 251
2- "Corrosion of Iron and Steel" p. 80
3- Friend's "Corrosion of Iron and Steel" p. 251
4- "Technology of Paint and Varnish" by Sabin, p. 190
5- "Corrosion and Preservation of Iron and Steel" by Cushman and Gardner, p.121
6- "Corrosion and its Prevention" by Newman, p. 17
7- "Corrosion and its Prevention", Newman, p. 23
8- Goulding in "The Journal of the Chemical Society of London", 1905;Cribb in "The Analyst" for 1905; and Whitney in "The Journal of the American Chemical Society" for 1903

2- The peroxide theory advanced by Traube. This has to do with the oxidation of iron by hydrogen peroxide. It is discredited by nearly all authorities on corrosion.

3- The electrolytic theory. This assumes that before the iron can oxidize, it must pass into solution as a ferrous ion. This theory is now accepted by nearly all writers. It is treated conclusively by Cushman and Gardner[1].

By its means, every phenomenon connected with the rusting of iron can be satisfactorily explained. Thus the rapid corrosion of the dryer cars can be understood when it is noted that such an electrolyte as sulphurous acid is present in the dryer, and is dissolved in the water that condenses upon the cars.

The electrolytic theory is too long to be fully discussed here. Excellent material upon the subject may be found in Cushman and Gardner's "Corrosion and preservation of Iron and Steel", "The Corrosion of Iron and Steel" by Sang, and "The Corrosion of Iron and Steel" by Friend. Specific instances of electrolytic action are cited in "Rustless Coatings" by Wood.

The rate of corrosion is greatly affected by the physical condition of the metal[2]. Laminations in a piece of steel rust out much more quickly than the rest of the piece. The laminations are often due to cinder in the metal which opens up the piece to the action of the corrosive agents. The cinder is acid in character and also directly aids the corrosion.

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[1] "Corrosion of Iron and Steel", p. 56

[2] "Rustless Coatings" by Wood, p. 332 and 344

A state of stress or strain aids corrosion as do also bubbles or blow holes.[1] These strains are said by Sang[2] to be due to carelessness of manufacture. The rolling and cooling of the metal is carried on at such a high speed that the molecules are not given time to readjust themselves, and a strain is set up. Such strains are present in all commercial steel of today, and partially account for the fact that modern structural material is more easily corroded than that made several years ago when more care was taken with the manufacture. Jackson[3] states that the rate of corrosion increases practically in proportion to the strain. This accounts for the increased corrosion around rivet holes and sheared edges.

lll. Classes of Coatings and Results of Previous Tests upon some Paints

The protective coatings may be divided into three classes;

1- Paint coatings, including linseed oil paints, varnishes, lacquers, bitumens, cements, and enamels.

2- Magnetic oxide surfaces.

3- Coatings of other metals.

The cheapest and most common paint used is one containing linseed oil as a vehicle. Investigations by Spennrath[4] however, show the futility of using an oil paint under the conditions found

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1- "Corrosion of Iron and Steel" by Cushman and Gardner, p. 2

2- Proceedings of the Engineering Society of W. Pa., vol. XXlV, p. 511

3- Transactions of the American Society of Mechanical Engineers, vol. XXll

4- "Protective Coatings for Iron" p. 21

in a waste heat dryer. He used graphite as a pigment in these tests, and pure,boiled linseed oil as the vehicle. Since the graphite was perfectly inert and unaffected by the chemical agents present, any failure was undoubtedly due to the oil.

Several paints, each containing a different per-centage of linseed oil, were exposed to a temperature of 203 degrees Fahrenheit for several days and in each case the paint became stiff and brittle and shortened from 3 to 4 per-cent.

A coating of the same material was suspended over a solution of gaseous sulphurous acid. It was destroyed within a few days and passed off in drops.

Spennrath states that there is no remedy against the injurious influences attacking the binding material.

In several paint tests in which the paints were exposed to the influences of sulphurous acid gases and weathering conditions, it was found that asphaltic paints and compounds of rubber lasted very poorly[1].

Cushman and Gardner[2] state that railroad tunnels, whose atmosphere is rich in sulphur dioxide, carbonic acid, and moisture, call for the very best inhibitive paints that it is possible to design. In train sheds, in which the girders were constantly surrounded with smoke from the locomotives, the only satisfactory paint found was a linseed oil varnish. No other paint had the ability to long withstand the corrosive agents. The heat in a waste heat dryer prohibits the use of such a coating for dryer cars.

1- Engineering News, vol. 148, p. 164

2- "Corrosion of Iron and Steel", p. 218

Tar paints were also found to fail completely in a position where they were continuously surrounded with coal smoke[1]. Tar coatings are seldom if ever pure and produce rust through the acetic acid that they contain[2].

Asphalt must be pure to be used in paints. In this state it is costly. It also becomes hard and brittle when cold and cracks easily. It is easily weathered by atmospheric influences.

Rubbing down with graphite has been practiced in some cases. Spennrath states that this is of little value since it is impossible to completely cover the surface and the metal soon corrodes.

Organic fats produce rust through the fatty acids that they contain[3].

Varnishes are composed of resins dissolved in linseed oil. Since sulphurous acid so vigorously attacks the oil, such coatings would be useless.

Lacquers were found by Walker[4] to actually stimulate corrosion when acids were present. They are also porous and allow the penetration of aqueous solutions[5].

Baked japan coatings composed of pure bituminous matter dissolved in gum or oil should afford an excellent means of protection and will be tested.

Paint enamels are mixtures of varnishes with metallic

1- "Iron Corrosion" by Andes, p. 117
2- "Technology of Paint and Varnish" by Sabin, p. 185
3- "Protective Coatings for Iron" by Spennrath, p. 35
4- "Journal of Industrial and Engineering Chemistry", 1909, p. 754
5- "Corrosion of Iron and Steel" by Cushman and Gardner

pigments. Hence they are to be classed with varnishes or oil paint.

Certain cements whose bonding power relys upon the setting of some of the ingredients may be valuable and will be tried.

Portland cements are the best means of protection against rusting that are known. Where the metal is not liable to wear or jars, a wash of Portland cement gives adequate protection.

Certain oxides produced upon the surface of the metal prohibit corrosion under certain conditions. Iron boiled in potassium bichromate solution produces an oxide which inhibits rusting under atmospheric conditions. The oxide, however, loses this passivity in the presence of aqueous acids and upon heating[1]. Russia iron owes its ability to withstand rusting to an oxide coating which is produced by the action ofsteam at a high temperature. This scale is brittle and may be broken or worn off. It is also expensive to produce. It is of advantage, as a protection against corrosion, to produce upon the surface this passive oxide and then paint over it. Rusting will not take place for some time after the paint has been removed so that small spots exposed by wearing away of the paint may be repainted. Where paint is applied to the bare metal, it is not advisable to touch up worn places with new paint because rusting has undoubtedly taken place upon the exposed metal and spread for some distance under the surrounding paint. Covering up the rust only hides its action. Whenever the paint has been broken away in several places, the whole surface should be cleaned and recoated.

1- "Corrosion of Iron and Steel" by Sang, p. 97

Fraudlent Paints.

In order to increase sales, many companies advertise their paints as having properties which it is impossible for them to posess. Andes[1] refers to such paints as follows:

"When we read in a manufacturer's circular that he has invented and prepared a paint that is capable of destroying pre-existing rust, and thereby of preserving rusted iron from any further encroachment, it is evident that such a claim is an impossibility. If another maker avers that his product posesses magnetic or electrical properties, this is an absurdity, because any pigment ground up in, and therefore surrounded by, linseed oil or linseed varnish is thereby rendered altogether inert. Another manufacturer claims as an advantage for his paint that the pigment he uses, unlike those of others, does not undergo saponification with the oil in the varnish and therefore must be more durable. It is well known that no saponification occurs in paint and that the durability of a paint may be reduced by the action of an oxidizing pigment (red or white lead) on the oil or varnish, whereas an inert body exerts no action. Furthermore, in many instances, totally unjustifiable claims are put forward on behalf of certain pigments such as iron oxide or graphite in the form of scales quite visible to the naked eye. It is asserted that in these paints, the individual flakes are completely enveloped in varnish and lie one above another so as to actually form a number of coats of paint in one. If, however, the scales be examined through a

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1- "Iron Corrosion and Anti-corrosive Paints", p. 115

magnifying glass, they will be aparent as coarse, granular fragments with only a few lustrous plates. Hence the pigment cannot produce any such coating as is claimed".

The latter, commonly called scale armor paint, has been greatly advertised as a protective coating. It is shown by Spennrath to be of no more value than any oil paint. He also disclaims the value of any paint said to have electrical or galvanic action.

Certain pigments used in paints are active in producing rust. Wood[1] explains their action as being to dissolve portions of the iron, and to deposit the metal which they contain upon the surface of the iron. These deposits excite galvanic action and cause corrosion and pitting. Both mercury and copper salts are offenders in this way. Also salts of lead, antimony, tin, silver, carbon, and manganese are detrimental if they come in contact with the iron through decay of the paint film.

Metal Coatings

The metal coatings applied to iron are usually of nickel, zinc, lead, copper, or tin.

Lead and tin offer little or no protection. Iron plates coated with either of these metals rust in a very short time. Nickel must be over .02 of an inch thick to give an adequate protection. Iron dipped in molten zinc forms an alloy with the zinc and gives the most effective of all metallic coatings[2].

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[1] "Rustless Coatings", p. 344

[2] "Protective Coatings for Iron", Spennrath, p. 38

Copper is said to promote rust through galvanic action upon the iron[1]. At least it does not provide an adequate protection.

lV. Preparation of the Surface Before Painting.

Too much emphasis cannot be given the fact that the metallic surface to be protected must be absolutely clean and dry before applying the coating.

During storage, manufacture, etc. of the steel material, ample time is given for the formation of rust. Mulder states that "an iron article may remain bright for a long time but whenever any portion is attacked by rust, the latter will very quickly spread over the entire surface".

Mill scale is also present upon the surface. Its effect has already been discussed.

Andes[2] comments upon the effect of rust as follows:

" Rust is from the outset, the most powerful antagonistic influence to the resistant capacity of the succeeding paint unless it is entirely removed before the latter is applied".

We know that the presence of rust is favorable to the further production of rust since it contains moisture derived from the air, and also that rusting can take place under the paint film. The bond between rust and iron is very slight and no paint can be expected to adhere to or protect a corroded surface.

1- "Rustless Coatings" by Wood, p. 344

2- "Iron Corrosion and Anti-corrosive paints", p. 58

There are three methods of cleaning the surface. They are by pickling, scraping, or sand-blasting.

In the first method, the metal is immersed in a 10 to 20 per-cent solution of sulphuric acid and allowed to remain until the rust or scale loosens and falls off. This process is very effecient for cleaning the surface, and requires only about twenty minutes for the process, but many objections are registered against it on account of the difficulty in washing off the acid. Should any of the acid remain, it will produce additional rust. The effect of any acid remaining, however, may be counteracted by washing in a bath of milk of lime.If correctly carried out, this method is the cheapest and most effecient for removing rust or scale[1].

Scraping off the rust is accomplished by means of wire brushes which are rubbed against the surface. This does not remove the rust from pit-holes, nor is it economical.

Sand blasting is a very cheap and quick method for cleaning iron. It requires, however, suitable apparatus with air under pressure and so is not suitable to every plant.

The paints should be applied immediately after cleaning the iron[2]. Rust forms very quickly and easily upon a clean iron surface and, should the metal be allowed to stand in the atmosphere before painting, a small amount of moisture will condense upon the surface, causing some rust to form and preventing the perfect adherence of the protective coating.

1- "Corrosion and its Prevention" by Newman, p. 130

2- American Society for Testing Materials, vol. 5, p. 436

Paints, if applied to a hot metal surface, afford greater protection through rapid rying and complete absence of moisture. This method has been practiced in painting ships by admitting steam into the hold and heating up the metal sides just before painting. Paints applied under these conditions have shown increased lasting qualities.

Oil or grease upon the surface of the iron prevents the paint from sticking and so is a detrimental factor.

V. Paints Tested in This Work and Results of the Tests

It is evident that the use of several paints, varnishes, and other coatings is precluded. Those whose values have not been determined are acid proof cements, baked japan coatings, and commercial paints whose composition is unknown.

Concerning the latter, about twenty of the larger paint companies were asked to submit samples of their paints to be tested under dryer conditions. Only three paints were obtained. These were The Southern Cotton Oil Company's metal coat #27, protective enamel #6 from The General Bakelite Company, and Toch Brothers' #44 R.I.W.

The fact that only three concerns had paints for use under the conditions of a waste heat dryer, shows the difficulty of obtaining any suitable coating. Nearly all of these companies have paint specalists and research laboratories employed for the purpose of discovering suitable protective coatings for use under such severe conditions as are present in this case. In the majority of cases, these inquiries were referred to these research labor-

atories and the answers were, as a rule, very discouraging in that no paints were known which could be recommended for such a purpose.

In addition to the above paints, aluminium bronze paint and bicycle paint were thought to be feasable. Aluminium bronze paint is used in chemical laboratories to some extent for protecting iron pipes against the action of acid fumes. A commercial sample was obtained for the test.

The bicycle paint was made up with the following ingredients: oil of tar, 4 parts; pure asphaltum, 1 part; and powdered resin, 1 part.

Two cements were made up; the first containing 100 parts of india rubber softened by heat, 6 parts of tallow, dry slaked lime added until the mixture assumed the consistency of a soft paste, and lastly about 20 per-cent of red lead was added to make it dry and harden.

The second cement was made of 3 parts of barium sulphate mixed with 2 parts of ground asbestos and 2 parts of sodium silicate.

The baked japan coating was made by melting 1 part of the mineral Gilsonite and dissolving in 5 parts of turpentine.

In addition to these coatings, one plate was boiled in a solution of potassium bichromate, while another was coated with a linseed oil paint using white lead as a pigment. The latter was tested as a means of verifying previous results and as a comparison with the other coatings.

The plates used in the tests were of soft rolled steel, about five inches long, two and one half inches wide, and three sixteenths of an inch thick. They were cleaned by immersing in a

20 per-cent solution of sulphuric acid until all of the scale was removed, and then boiling in several changes of water until all of the acid was washed off. They were then quickly dried and placed in a desiccator containing calcium chloride, until ready for use.

All of the paints were applied by dipping with the exception of Toch Brothers' #44 R.I.W. which was put on with a brush. Three coats were applied in each case, and one coat was allowed to become thoroughly dry before applying another.

None of the coatings showed preliminary defects with the exception of the asbestos cement and the baked japan coating. The latter was very brittle after baking and was easily chipped off, while the cement was soft and could be crumbled and scarred with the finger nail.

When all of the coatings had become dry and hard, the plates were placed in an electric oven and kept at a temperature of 120 degrees Centigrade for two weeks.

The oil paint cracked and curled up within a few days.

Toch Brothers' #44 R.I.W. softened considerably at first, but gradually became harder and finally became almost brittle.

The india rubber cement became soft and sticky and remained so until the end of the heating period.

The asbestos cement did not change.

The Southern Cotton Oil Company's metal coat #27 became harder and adhered more firmly to the surface of the plate. It seemed to be in excellent condition at the end of the two weeks.

The Bakelite coating was not at all affected.

The aluminium bronze coating became soft and sticky

at first but hardened after a few days baking.

The bicycle paint became fairly soft and did not harden upon further baking.

The baked japan coating did not change.

After the baking test, the plates were suspended in a closed vessel over a saturated solution of sulphurous acid, and water vapor was allowed to condense upon them. They were kept in this position for about two months, while fresh solutions of the acid were put in from time to time.

The Bakelite and Toch Brothers' coatings were not at all affected. There was no perceptible formation of rust.

The Southern Cotton Oil Company's metal coat #27 turned yellow in spots, becoming less elastic and rather easily scraped off the plate.

Corrosion was soon perceptible under the asbestos cement.

The rubber cement became hard and lost its bond with the plate, allowing the acid to reach the metal underneath.

Rust soon formed under the aluminium bronze coating, and it came off in scales.

The baked japan coating was not affected.

The bicycle paint lost its lustre and, upon jarring loose from the plate, it was found to have allowed the penetration of the acid solution since spots and lines of rust had been formed.

The oil paint in itself did not seem to be affected. However, the cracks caused by the previous heating had allowed the acid to come in contact with the metal and rust had formed.

The plate boiled in potassium bichromate did not long

withstand the action of the acid. The surface was covered with rust within a few days.

An unprotected plate was greatly rusted within twelve hours from the beginning of the test.

As a final test, the plates coated with Bakelite, Toch Brothers' #44 R.I.W., linseed oil paint, and The Southern Cotton Oil Company's metal coat #27 were partly immersed in the acid solution and allowed to stand for two weeks.

At the end of this time,the Bakelite and Toch Brothers' coatings were not affected except on the edges where the paint had not fully covered the metal.

The oil coating was rotten and could be easily scratched off.

The Southern Cotton Oil Company's metal coat #27 had completely disappeared where it had been covered with the acid solution.

Results of the Brittleness and Resistance to Friction Tests

As a means of testing the relative hardness or resistance to friction, a device was constructed which allowed clean quartz sand to fall upon the coated plates in streams about one-eighth of an inch in diameter, and from a height of three feet. The length of time required for the sand to wear through the coating to the steel plate was the basis of comparison. The thickness of the coatings was not measured. Since three coats of the paint just as prepared commercially should, and probably would, be applied in practice, tests upon paint films of equal thickness

would not be of practical value.

The coatings were tested for brittleness or adhesivness by dropping a two inch steel ball upon the coated plate from different heights. The plate was supported at both ends and the ball was dropped upon the center.

The results of the tests were as follows:

Coating	Hardness. Time required to wear through the coating.	Brittleness. Height from which the ball was dropped before coating was broken through.
Bakelite	11 hours	No cracks were developed when the ball was dropped from a distance of ten feet. The surface was only indented.
Toch Brothers' #44 R.I.W.	8 hours	The coating was cracked completely off in spots when the ball was dropped only six inches.
Southern Cotton Oil Company's metal coat #27	4 & 1/2 hours	The coating did not crack but was considerably bruised when the ball was dropped from a height of six feet.

Vl. Use of Different Material in the Cars

Since the protection of the dryer cars is such a difficult problem, it should not be out of place here to discuss the use of other materials which are not so easily corroded as the type of steel commonly used.

While it is known that cast iron under certain conditions

has a slower rate of corrosion than rolled steel, many writers assert that the former is more acted upon by acids than the latter. However, this is not the case in waste heat dryers. In at least three different cases, it was observed that the wheels and standards of the cars, which were of cast iron, were very little affected by the gases while the slats of the decks, which were of rolled steel, were covered with a layer of rust of at least one-third of the original thickness of the bar. This resistance to corrosion is said to be due to both physical and chemical make-up and also to the fact that a thin, silicious skin is formed upon the surface of the casting by contact of the molten metal with the sides of the mold.

The explanation given by Stead[1] for the resistance of cast iron to the action of sulphuric acid is that a thin, protective film of ferrous sulphate is formed upon the surface of the metal.

Friend[2] states that white cast iron resists the action of acids better than the grey variety, but the former is more brittle and would probably not be as valuable as the tougher, grey variety.

A grade of steel called ingot iron is now being made by the American Rolling Mills Company of Middletown, Ohio, which is advertised as being much less liable to corrosion than ordinary structural material. Being a fairly new product, its true worth has not yet been definately established. A dryer car of this

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1- Journal of the Iron and Steel Institute, 1908

2- "Corrosion of Iron and Steel", p. 117

material has recently been made for the Western Brick Company at Danville, Illinois and is now being tried out in their dryer. The test has not been carried out long enough as yet to be of value. The cost of this non-corrosive steel is only about 10 per-cent above that of the ordinary structural steel so the use of the former would be justified should it lengthen the life of the cars to any extent. The analysis of ingot iron as determined by Friend[1] is as follows:

Sulphur	0.021%
Phosphorous	0.005%
Carbon	0.02%
Manganese	Trace
Silicon	Trace
Iron (by difference)	99.954%

Plates of this metal, of charcoal iron, and of ordinary steel were carefully polished and placed in a 25 per-cent solution of sulphuric acid at a temperature of 110 degrees Centigrade for a period of one and one-half hours. They were then removed, cleaned, and weighed. The following results were obtained:

Metal	Loss in Weight
Steel	87.5%
Charcoal iron	52.1%
Pure ingot iron	2.16%

In addition to the different types of metal such as cast iron, ingot iron, etc. there are many alloys of iron and steel which show different rates of corrosion.

1- "Corrosion of Iron and Steel, p. 114

Cushman[1] states that "In considering the corrosion of iron, it is important to remember that iron is a metal which readily combines with, or dissolves, nearly all of the other elements, and that very small quantities of impurities suffice to change entirely its physical properties or characteristics".

Nickel, cobalt, tin, copper, chromium, phosphorous, and silicon, when alloyed with iron or steel, decrease the tendency toward rusting, while aluminium, manganese, antimony, arsenic, sulphur, and carbon increase corrosion[2,3,& 4].

These impurities are never found uniformly dissolved in iron or steel so that a solid piece of metal may corrode much more rapidly in one place than in another.

While copper alone decreases rusting, it is usually found compounded with sulphur. The sulphide is easily oxidized and produces a corrosive acid so that copper may be considered as being a detrimental constituent unless the steel contains little or no sulphur.

Experiments carried out by The Carnegie Steel Company[5] show that Bessemer steel corrodes more rapidly than open-hearth steel, and that an acid open-hearth steel corrodes more rapidly than a basic open-hearth steel. It was also found that wrought iron corrodes more rapidly than steel in almost all cases, and that the higher the carbon in steel, other things being equal,

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1- "Corrosion of Iron ans Steel", p. 9
2- Iron and Coal Trades Review, vol. 78, p. 341
3- "Corrosion of Iron and Steel" by Friend, p. 209
4- "Corrosion of Iron and Steel" by Sang, p. 82
5- "Corrosion of Iron and Steel" by Sang, p. 57

the more rapid the corrosion.

In a paper upon "The Corrosion of Iron and Steel", Edward Crowe stated that phosphorous in steel was a very powerful antidote to corrosion. Diegel[1] found by experiment that the corrosion of steel was in inverse proportion to the phosphorous content.

Vll. Discussion and Conclusion

It is evident that, with the exception of Bakelite, there are no very satisfactory coatings for use on dryer cars. The conditions under which the cars are used are probably the most severe to which a paint is ever subjected. Andes[2] says that "No paint will resist the action of smokey fumes evolved from coal fires, and it is as yet impossible - all promises to the contrary notwithstanding - to provide an effecient protection for iron bridges and other structures exposed to such influences."

By "effecient protection" is meant a protection which will increase the length of the life of the cars at least enough to pay for the application of the coating. Then, according to Andes, it is a waste of time and money to attempt the protection of dryer cars by means of any known coating. Whether this is true or not, it is impossible to say. It seems to be borne out, however, by all experience with such coatings. The tests upon the coatings herein were merely relative, and nothing can be said concerning their life in actual practice. Plates coated with the three

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[1] Iron and Coal Trades Review, 1909, p. 341

[2] "Corrosion of Iron and Steel", p. 117

commercial paints- Bakelite, Toch Brothers', and the Southern Cotton Oil Company's- were sent to the Western Brick Company at Danville, Illinois to be tested in their dryer. Having been sent only a few weeks ago, nothing is known as yet of their practical value. The laboratory tests, however, indicate that Bakelite is the only one which will be of practical value. The paint from The Southern Cotton Oil Company fails in contact with sulphur dioxide and water, while Toch Brothers' paint is too brittle to be of any practical value. All are hard enough to withstand rather severe wearing conditions. The fact that Bakelite withstood,in an entirely satisfactory manner, the action of sulphurous acid, and that it had extreme hardness and tenacity, indicates that it would afford a truly effecient means of protection for dryer cars.

The cost of Bakelite in 400 pound lots is thirty-five cents per pound. The Southern Cotton Oil Company's metal coat #27 costs ninety cents per gallon. No prices were quoted on Toch Brothers' #44 R.I.W. The spreading value of Bakelite as given by the manufacturers is 110 square feet per pound for one coat, while that of The Southern Cotton Oil Company's paint is given as 300 square feet per gallon so that the cost per square foot is approximately the same.

Since the increased life of the cars is the vital point to be considered, the best must be made of a very difficult problem. On account of the high cost of steel and the expense of replacing rusted bars with new ones, it would seem that coatings lasting only two or three months would be of value. However, this can only be determined through practical experience. The life of the coating can be greatly lengthened by using extreme care in the

preparation of the surface and in the application of the paint.

The use of cast or ingot iron seems to be the best solution of the problem. Cast iron is brittle and heavy, but with correct construction, these difficulties could be cut down until they were more than offset by the higher cost and shorter life of the rolled steel.

Ingot iron is just coming into use. Should it prove as rust-resisting as advertised, it will make unnecessary the use of any protective coating.